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ENVIRONMENTAL EXPOSURE TO LEAD AND CHILDREN'S INTELLIGENCE AT THE AGE OF SEVEN YEARS

The Port Pirie Cohort Study

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Abstract *Background.* Exposure to lead in early childhood is thought to result in delayed neuropsychological development. As yet there is little longitudinal evidence to establish whether these effects persist into later childhood.

Methods. We measured IQ scores in 494 seven-year-old children from the lead-smelting community of Port Pirie, Australia, in whom developmental deficits associated with elevated blood lead concentrations had already been reported at the ages of two and four years. Exposure to lead was estimated from the lead concentrations in maternal blood samples drawn antenatally and at delivery and from blood samples drawn from the children at birth (umbilical-cord blood), at the ages of 6 and 15 months and 2 years, and annually thereafter. Data relating to known covariates of child development were collected systematically for each child throughout the first seven years of life.

Results. We found inverse relations between IQ at the age of seven years and both antenatal and postnatal blood lead concentrations. After adjustment by multiple regression for sex, parents' level of education, maternal age at delivery, parents' smoking status, socioeconomic status, quality of the home environment, maternal IQ, birth weight, birth order, feeding method (breast, bottle, or both), duration of breast-feeding, and whether the child's natural parents were living together, the relation with lead exposure was still evident for postnatal blood samples, particularly within the age range of 15 months to 4 years. For an increase in blood lead concentration from 10 μg per deciliter (0.48 μmol per liter) to 30 μg per deciliter (1.45 μmol per liter), expressed as the average of the concentrations at 15 months and 2, 3, and 4 years, the estimated reduction in the IQ of the children was in the range of 4.4 points (95 percent confidence interval, 2.2 to 6.6) to 5.3 points (95 percent confidence interval, 2.8 to 7.8). This reduction represents an approximate deficit in IQ of 4 to 5 percent.

Conclusions. Low-level exposure to lead during early childhood is inversely associated with neuropsychological development through the first seven years of life. (N Engl J Med 1992;327:1279-84.)

EXPOSURE to low levels of lead in childhood may result in impaired neuropsychological development and classroom performance.[1] The extent of this relation, however, after adjustment for the confounding effects of socioeconomic and environmental covariates, has been debated.[2-17] Taken together, the epidemiologic studies indicate a moderate inverse relation between the body burden of lead (measured as blood or tooth lead concentrations) and the neuropsychological or cognitive performance of children.[18-22] Whether the effects disappear once lead exposure ceases or whether early exposure to lead has effects on neuropsychological development that persist into later life is uncertain. Longitudinal studies are clearly the best way to address this question.

The Port Pirie Cohort Study began in 1979. Early results showed considerable interindividual variation in blood lead concentrations during early childhood,[23-25] with approximately one third of the children in this lead-smelting community having concentrations above 25 μg per deciliter (1.21 μmol per liter) on one or more occasions. Mental development was found to be inversely associated with postnatal blood lead concentrations at the ages of two and four years, after adjustment for confounding factors.[6,7] It was estimated that a child with a blood lead concentration of 30 μg per deciliter (1.45 μmol per liter) had a deficit of 3.3 points (approximately 3.2 percent) on the Bayley Mental Development Index at the age of two years, and of 7.2 points (approximately 6.7 percent) on the McCarthy General Cognitive Index at the age of four years, as compared with a child with a blood lead concentration of 10 μg per deciliter (0.48 μmol per liter). The cohort has now been followed into the primary-school age range. This paper examines intelligence at the age of seven years in relation to lifetime exposure to lead.

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METHODS

The Cohort

The original study population comprised 723 singleton infants born in and around Port Pirie, South Australia, during the three-year period from 1979 to 1982. These infants represented an estimated 90 percent of all singleton live births in the community during this period. Of the 516 children who remained in the study through the age of seven years, developmental status (including intelligence) was assessed in 494 within the specified age range of seven to eight years.

Data Collection

Four trained nurse-interviewers collected up to three venous-blood samples from each mother before delivery, a sample from the umbilical cord at birth, and capillary-blood samples from each child at the ages of 6 and 15 months and 2 years, and annually thereafter.[23,24] A pilot study demonstrated that the lead concentrations in

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capillary-blood samples, collected according to a strict protocol, were highly correlated (r = 0.97) with the lead concentrations determined in venous-blood samples taken from 47 children who were two to four years of age.

At the time of each blood sampling, the nurse-interviewer also conducted a structured interview to obtain information on a range of demographic, psychosocial, medical, and environmental factors.

Measurement of Blood Lead Concentrations

Blood lead concentrations were measured by electrothermal atomization atomic-absorption spectrometry.[26] The analyses were subject to internal and external quality-control procedures, with consistently satisfactory results.[24] The results were standardized to a packed-cell volume of 35 percent for all samples except cord blood, for which a value of 50 percent was used.

Developmental Assessment

The IQ of each child was measured under uniform conditions by means of the revised version of the Wechsler Intelligence Scale for Children (WISC-R).[27] The WISC-R comprises 10 sequentially administered subscales. Although they do not in themselves measure discrete neuropsychological functions, the first five subscales (information, similarities, arithmetic, vocabulary, and comprehension) are used to estimate a verbal IQ, and the remaining subscales (picture completion, picture arrangement, block design, object assembly, and coding) are used to estimate a performance IQ. All children were evaluated by the same research psychologist, who was unaware of each child's lead-exposure status. Although the psychologist had also assessed the child's abilities at the ages of two and four years, he was not formally aware of the earlier results. The median age of the children on the day of testing was 186 days after their seventh birthday (the 25th and 75th percentiles were 132 and 246 days, respectively).

Covariate Measures

Other factors likely to confound the relation between lead exposure and IQ, and for which ancillary information was collected, included socioeconomic status (established with use of Daniel's Scale of Prestige of Occupations in Australia[28]), the care-giving environment (assessed by the Home Observation for the Measurement of the Environment [HOME] inventory[29]), maternal intelligence (measured with the Wechsler Adult Intelligence Scale[30]), parental smoking habits and years of secondary education, whether the parents were living together, the birth weight and birth order of the child, and the duration of breast-feeding during infancy.

Statistical Analysis

Statistical analyses were performed on the natural logarithm of the blood lead concentration, and all reported mean values are geometric. For each child, a curve plotting the blood lead concentration against age was constructed. The lifetime average blood lead concentration up to a particular age was estimated by dividing the appropriate area under the curve by the specified age.

The effects of potential confounding factors were investigated by multiple regression analysis with (log) blood lead concentration as a continuous explanatory variable. The covariates used in the final models included sex, birth weight, birth order, feeding method (breast, bottle, or both), duration of breast-feeding, parents' level of education, maternal age at delivery, parents' smoking status, socioeconomic status, quality of the home environment, maternal IQ, and whether the child's natural parents were living together.

Results

Loss to Follow-up

The 207 children born into the cohort but subsequently lost to follow-up were similar to the 516 who remained in the study with respect to 12 of the 15 variables studied. The socioeconomic status of the children lost to follow-up was slightly lower, more of their mothers smoked (35 percent vs. 27 percent), and fewer were breast-fed during infancy (32 percent vs. 37 percent). The mean umbilical-cord blood lead concentrations for the two groups were almost identical (9.3 vs. 8.9 μg per deciliter [0.45 vs. 0.43 μmol per liter]).

Blood Lead Concentrations

The geometric mean lead concentrations in maternal blood collected both antenatally and at delivery, in cord blood, and in capillary samples collected throughout childhood are shown (according to quartile) in Table 1. The blood lead concentrations were highest at the age of two years; by the age of seven years the mean values had fallen by over 40 percent. Lifetime averages at each age are also shown.

Age-Specific Blood Lead Concentration and Children's IQ

The mean scores for verbal IQ, performance IQ, and full-scale IQ were 103.1 (95 percent confidence interval, 101.8 to 104.4), 105.9 (95 percent confidence interval, 104.6 to 107.1), and 104.7 (95 percent confidence interval, 103.5 to 106.0), respectively. There was a consistent inverse relation between the blood lead concentrations and scores on all IQ scales (Table 2). The mean IQ scores differed by 2.7 to 12 percent between the children with values in the highest and lowest quartiles for blood lead concentration.

The unadjusted relation between IQ and lifetime average blood lead concentration at the age of seven years is shown in Figure 1. For each IQ scale, there was an inverse gradient across most of the range of blood lead concentration. There is a suggestion that this gradient was less steep at higher exposures (>20.0 μg per deciliter [>0.97 μmol per liter]), but because of the paucity of children with such exposure levels, there is greater statistical variability associated with these higher exposures. The gradient is steeper for verbal IQ than for performance IQ. The proportion of the variance of full-scale IQ that could be accounted for by the blood lead concentration at different ages (without consideration of the covariates) varied from 1.4 to 6.1 percent.

Other Covariates and Children's IQ

The unadjusted mean IQ scores for subgroups divided according to covariates that may confound the relation between lead exposure and IQ are shown in Table 3. Many sociodemographic factors and neonatal or infant characteristics were strongly related to the child's IQ, in the anticipated direction. Socioeconomic status, the quality of the home environment, and maternal intelligence were the variables most strongly associated with IQ and in simple regression analysis accounted for 8.4, 12.0, and 13.3 percent, respectively, of the variance of the full-scale IQ. Sex and birth order of the child were not significant correlates of IQ.

In simple regression analyses all measures of blood lead concentration (antenatal, delivery, and postnatal averages) were significantly inversely associated with verbal, performance, and full-scale IQ. The inverse relation of the blood lead concentration to verbal IQ was consistently stronger than its relation to performance IQ. In multiple regression analyses (Table 4), the effect of adjusting for the covariates in Table 3 was to attenuate markedly the apparent association of the child's IQ with the various measures of blood lead concentration. In particular, the regression coefficients associated with the lead concentrations in antenatal, delivery, and cord-blood samples became insignificant. The covariates contributing most to this attenuating effect were those identified as being most closely related to IQ: socioeconomic status, HOME score, and maternal IQ. However, for lifetime average blood lead concentrations ranging from birth through 15 months to birth through 4 years, there were statistically significant inverse associations with verbal IQ and full-scale IQ. On the basis of regression analysis, an increase in blood lead concentration from 10 to 30 μg per deciliter (0.48 to 1.45 μmol per liter) was associated with a deficit in verbal IQ that varied according to age from 5.5 to 6.4 points (5.3 to 6.2 percent), and in full-scale IQ the estimated deficit was 4.4 to 5.3 points (4.2 to 5.1 percent). The largest changes in response to adjustment for covariates were in the relation of blood lead concentration to performance IQ.

Table 1. Mean Blood Lead Concentration (within Quartiles) in Maternal Samples Taken Antenatally and in Children's Samples at Various Ages.

Quartile	Blood Lead Concentration*									
	Average Antenatal	Umbilical Cord	Age							
			6 mo	15 mo	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr
	micrograms per deciliter									
Mean concentration										
I (low)	6.2	4.3	8.3	11.8	13.0	11.6	9.5	8.3	7.2	6.6
II	8.7	7.4	12.6	18.6	18.6	17.4	14.7	12.6	11.2	10.1
III	10.6	9.9	16.8	24.4	24.2	22.4	19.0	17.2	14.7	13.7
IV (high)	14.3	15.0	24.2	34.4	33.5	30.2	26.5	23.6	20.5	20.0
Mean lifetime average concentration										
I (low)	—	—	7.4	9.9	11.6	12.2	12.2	11.8	11.2	10.8
II	—	—	10.6	14.3	16.6	17.4	17.6	17.0	16.4	15.7
III	—	—	13.5	18.0	20.5	21.7	21.5	21.1	20.3	19.7
IV (high)	—	—	18.4	23.8	27.1	28.2	27.7	26.9	25.9	24.8

*To convert values for lead to micromoles per liter, divide by 20.7.

The estimated linear inverse relation between log average blood lead concentration and full-scale IQ, determined with use of the covariate-adjusted coefficients at the age of 3 years in Table 4, is shown in Figure 2 (there are similar relations at other ages, but the age of 3 is centrally located in the range of apparently maximal sensitivity — 15 months to 4 years of age). The girls were more sensitive to the effects of lead than were the boys. For an increase in blood lead concentration from 10 μg per deciliter (0.48 μmol per liter) to 30 μg per deciliter (1.45 μmol per liter), the expected covariate-adjusted decrement in full-scale IQ was 7.8 points for the girls and 2.6 points for the boys.

Simple and Multivariable Analyses of Subscale Scores

Simple and multivariable analyses of WISC-R subscale scores showed that the mean subscale scores varied inversely with the lifetime average blood lead concentrations. However, the apparent sensitivity of the components of the WISC-R to the blood lead concentration differed. The associations between lifetime average blood lead concentration and the information and block-design subscales were stronger than those for any other subscales (Table 5).

Table 2. Mean Verbal, Performance, and Full-Scale IQ Scores of the Seven-Year-Old Subjects, According to the Quartile for Blood Lead Concentration at Various Ages.*

Quartile	Average Antenatal	Umbilical Cord	Age				
			6 mo	15 mo	3 yr	5 yr	7 yr
Verbal IQ score							
I (low)	107.3	106.9	107.9	107.9	109.0	108.4	108.2
II	103.9	104.6	102.8	105.4	104.4	104.5	106.4
III	102.8	99.4	101.7	101.0	100.7	102.2	100.5
IV (high)	98.6	101.7	98.0	99.8	98.5	96.8	97.1
Performance IQ score							
I (low)	108.2	108.7	109.5	109.2	109.6	108.7	109.4
II	107.0	106.1	106.0	106.7	107.8	106.8	107.9
III	107.0	103.4	104.1	104.7	103.8	105.6	105.0
IV (high)	101.4	105.8	102.4	102.9	101.8	101.6	100.9
Full-scale IQ score							
I (low)	108.5	108.4	109.4	109.3	110.2	109.3	109.6
II	105.7	105.8	104.7	106.5	106.5	106.1	107.7
III	105.1	101.3	102.9	102.9	102.2	104.1	102.7
IV (high)	99.8	103.9	100.0	101.3	100.0	98.8	98.7

*Differences between quartiles were statistically significant ($P<0.01$) in every instance except for the variation of performance IQ scores with cord-blood lead concentrations ($P = 0.05$).

Discussion

These results indicate that the inverse associations between blood lead concentration and indexes of development reported earlier for this cohort[6,7] persist into the primary-school years. The strong correlation ($r = 0.65$, $P<0.001$) of the full-scale IQ at the age of seven years with the McCarthy General Cognitive Index at the age of four years[6] indicates that many of the children who scored poorly initially have not had great improvements in their overall ranking by the age of seven years.

Two prospective studies have found that the lead concentration in the umbilical-cord blood is predictive of developmental progress in early childhood.[2,3] However, in a subsequent report from one of these study groups, the scores of the children on the McCarthy Scales of Children's Abilities at the age of 57 months were inversely related to the blood lead concentration at 24 months of age, but not to the umbilical-cord blood lead concentration.[32] This result is compatible with our overall finding of no significant relation between IQ and antenatal or perinatal blood lead concentration after other covariates are taken into account.

The conclusions reached in this study are likely to be conservative for several reasons. First, the children remaining in the cohort had slightly more advantaged backgrounds than those lost to follow-up. Since children from disadvantaged families may be more vulnerable to the effects of lead than those from more favorable backgrounds,[3,31] the inverse relation of lead to IQ might have been stronger among the children lost to follow-up than among those remaining in the cohort. Second, the use of certain covariates in multivariate analyses may result in an overadjustment in studies of the association between lead and IQ.[6,31,32] Parental smoking status, the quality of the home environment, and maternal IQ may themselves contribute to a child's lead burden,[2,3,6,7,33] in which case some of the true effect of lead would have been removed by controlling for these factors. Third, randomly distributed imprecision or misclassification in the measurement of lead exposure (or its confounders) will bias the estimate of the effect toward the null value.[33]

Although the estimates presented here are likely to be conservative for the reasons described above, the possibility that we did not completely control for positive confounding variables and subsequently overestimated the true effect cannot be completely eliminated. For example, the developmental effects of anemia could bias the study.[34,35] After the exclusion of the 10

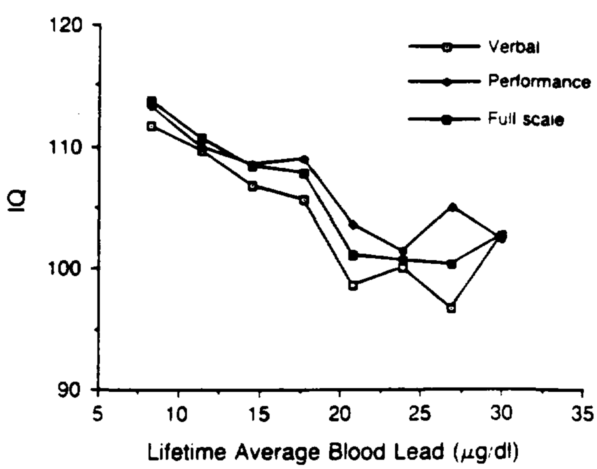

Figure 1. Lifetime Average Blood Lead Concentration and IQ at the Age of Seven Years.

To convert blood lead concentrations to micromoles per liter, divide by 20.7.

Table 3. Effect of Potential Confounding Variables on Mean IQ Scores at the Age of Seven Years.*

Covariate	Blood Lead†	Verbal IQ	Performance IQ	Full-Scale IQ
	µg/dl			
Sex				
Male	17.2	104.4±0.9	105.9±1.0	105.4±0.9
Female	17.0	102.1±0.9	106.0±0.9	104.3±0.9
Mother's education level‡				
≤3 yr	18.2	100.0±0.8	103.4±0.9	101.7±0.8
>3 yr	15.5	106.7±0.9	108.8±0.9	108.4±0.9
Father's education level‡				
≤3 yr	17.2	101.2±1.0	104.8±1.0	103.0±0.9
>3 yr	16.1	106.6±0.9	108.6±0.9	108.3±0.9
Mother's age at child's birth (yr)				
<23	19.2	101.0±1.2	104.5±1.2	102.8±1.2
23–28	16.2	102.9±1.1	106.1±1.0	104.8±1.0
>28	16.4	105.6±1.1	107.1±1.1	106.8±1.1
No. of parents smoking				
None	15.9	105.5±0.9	107.6±0.8	107.1±0.8
One	17.4	101.3±1.1	104.1±1.2	102.7±1.1
Both	19.2	99.7±1.8	104.3±1.6	102.0±1.7
Socioeconomic status				
Lower	20.7	98.0±1.1	102.4±1.2	99.9±1.1
Middle	16.6	102.9±1.3	104.2±1.2	103.8±1.3
Higher	15.1	106.6±0.9	109.1±1.0	108.5±0.9
HOME scores				
<40	19.7	96.5±1.1	100.3±1.1	98.0±1.1
40–45	17.4	105.7±1.0	108.5±0.9	107.6±0.9
>45	14.1	107.5±1.2	108.9±1.3	108.9±1.2
Mother's IQ				
<85	20.7	97.1±1.4	99.6±1.6	97.8±1.3
85–95	17.0	101.0±1.2	106.1±1.3	103.6±1.2
>95	15.5	110.6±1.0	111.5±1.0	112.1±1.0
Birth weight (g)				
<2500	19.2	99.2±3.4	102.1±3.7	100.5±3.6
2500–3500	17.6	102.4±0.9	104.7±0.9	103.7±0.9
>3500	16.2	104.6±0.9	107.9±1.0	106.7±0.9
Birth order				
1st	17.4	103.2±0.9	105.8±1.0	104.8±0.9
2nd	16.6	102.7±1.2	106.8±1.1	105.0±1.1
≥3rd	16.4	103.4±1.4	105.0±1.4	104.4±1.4
Feeding style				
Breast	15.7	106.6±1.0	108.4±1.0	108.1±1.0
Mixed	14.7	105.4±2.3	105.0±2.7	105.6±2.6
Bottle	18.4	100.3±0.9	104.2±0.9	102.2±0.8
Months of breast-feeding				
0	19.0	98.3±1.3	103.0±1.4	100.4±1.3
1–6	17.4	102.7±0.9	105.2±0.9	104.2±0.9
>6	15.5	106.6±1.1	108.8±1.1	108.3±1.1
Parents living together				
Yes	16.6	103.5±0.7	106.4±0.7	105.3±0.7
No	20.3	100.8±1.8	102.4±1.9	101.5±1.8

*Plus–minus values are means ±SE.

†Values are the lifetime average blood lead concentrations at the age of seven years. To convert values for lead to micromoles per liter, divide by 20.7.

‡Years refer to the number of years of high school completed.

children who had a packed-cell volume of less than 34 percent at the age of seven years, however, the estimated regression coefficients for the blood lead concentrations changed little.

Because a child with a high blood lead concentration at one age is likely to have high concentrations at other ages (a phenomenon referred to as "tracking"), it is difficult to determine critical or sensitive periods for the effects of lead. However, the maximal effect of lead on IQ was found for lifetime average blood lead concentrations from birth to any age between 15 months and 4 years. This suggests that exposure to lead in the preschool age range has a maximal effect on IQ.

Among the WISC-R subscales, the information and the block-design subscales were the most sensitive to the effects of lead. Since the information subscale may be culturally dependent, its effects on the relation of the more objective block-design scores to the blood lead concentration were tested by including the information score as an additional covariate in the regression model. The association between log blood lead concentration and the block-design scores was only partially attenuated (regression coefficient, −1.00; 95 percent confidence interval, −0.42 to −1.58), which dispels the notion that the results are an artifact of the cultural environment. The block-design subscale tests a person's perceptual organization and synthesis, spatial visualization, nonverbal concept formation, and visual motor coordination. It also reflects the degree to which right and left cerebral functioning is integrated.[36] Impaired spatial discrimination has also been reported in adult monkeys exposed to low levels of lead for long periods.[37]

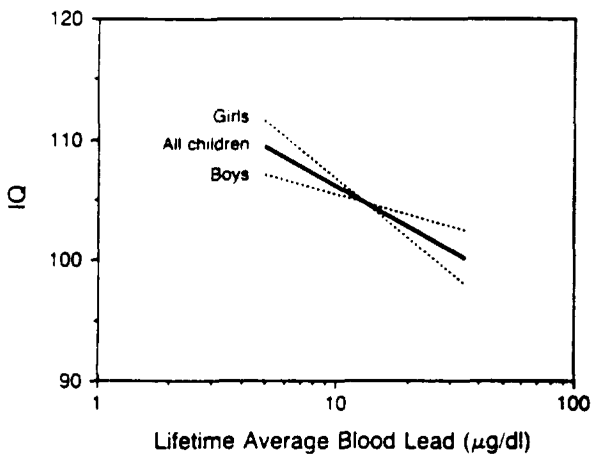

Figure 2. Estimated Relation between Full-Scale IQ at the Age of Seven Years and the Lifetime Average Blood Lead Concentration up to the Age of Three Years.

The line of best fit is shown, as estimated by multiple regression analysis. To convert blood lead concentrations to micromoles per liter, divide by 20.7.

The results indicate that the deleterious effects of environmental lead are not large, and that only a small fraction of the overall variation in IQ can be attributed to lead exposure. Nevertheless, the social consequences of such an effect are not negligible. If a child with an IQ of less than 80 requires educational assistance, then the number of children requiring assistance in a community whose children are expected to have a mean IQ of 105 will be doubled if the mean is reduced by approximately 5 percent as a result of lead exposure. Health authorities in the United States have recently estimated that for each reduction of 1 μg per deciliter (0.05 μmol per liter) in he blood lead concentration due to lead-exposure–ab itement programs, there would be a net saving to so ciety of approximately $2,000 per child, because th e need for clinical attention and remedial education and the expense of lost productivity could be avoided.[38]

The fact that an inverse association between the blood lead concentrations and abilities has been observed longitudinally at the ages of two, four, and seven years within this cohort suggests that even a low level of exposure to lead has an independent and enduring effect on neuropsychological development in childhood. From a public health perspective, the early detection and abatement of lead in the environment are highly desirable.

Table 4. Adjusted Coefficients of Log Lifetime Average Blood Lead Concentration from Multiple Regression Analyses of IQ Scores at the Age of Seven Years.*

Time Blood Sample Obtained	Verbal IQ	Performance IQ	Full-Scale IQ
Before birth†	−1.5±2.0 (0.46)	−1.0±2.1 (0.62)	−1.4±2.0 (0.48)
After birth (cord blood)	−0.1±1.4 (0.94)	1.0±1.5 (0.50)	0.6±1.4 (0.68)
0–15 Mo of age	−5.0±2.1 (0.03)	−2.3±2.2 (0.30)	−4.0±2.0 (0.04)
0–2 Yr of age	−5.8±2.2 (<0.01)	−2.4±2.2 (0.28)	−4.6±2.1 (0.03)
0–3 Yr of age	−5.7±2.4 (0.03)	−2.8±2.4 (0.24)	−4.8±2.3‡ (0.04)
0–4 Yr of age	−5.0±2.5 (0.04)	−3.3±2.5 (0.18)	−4.6±2.4 (0.05)
0–7 Yr of age	−4.3±2.6 (0.10)	−2.3±2.6 (0.37)	−3.7±2.5 (0.14)

*The coefficients were adjusted for all covariates shown in Table 3. Plus–minus values are means ±SE. P values are shown in parentheses.

†Blood samples were obtained antenatally from the mother.

‡This means that the expected decrement in full-scale IQ associated with an increase in average blood lead concentration from 10 to 30 μg per deciliter (0.48 to 1.45 μmol per liter) during the first three years of life is 5.3 points: 4.8 × (log[30] − log[10]) = 5.3.

Table 5. Mean Age-Adjusted Subscale Scores and Estimated Regression Coefficients for Lifetime Average Blood Lead Concentration up to the Age of Three Years.*

Subscale	Blood Lead Quartile†				Coefficient	
	I	II	III	IV	Estimate	P Value
Information	11.7	12.2	11.2	10.5	−1.45±0.57	0.01
Similarities	10.0	10.8	10.2	9.2	−0.90±0.62	0.14
Arithmetic	9.6	9.7	9.2	8.5	−0.51±0.63	0.42
Vocabulary	12.5	12.7	12.0	12.3	−0.44±0.51	0.40
Comprehension	10.0	9.6	9.6	9.2	−0.88±0.54	0.10
Picture completion	11.2	11.4	11.0	10.6	−0.15±0.45	0.74
Picture arrangement	10.2	10.7	10.2	9.9	−0.34±0.60	0.56
Block design	11.6	12.0	10.8	10.2	−1.61±0.62‡	0.01
Object assembly	11.4	11.7	11.4	10.9	−0.08±0.50	0.86
Coding	10.8	10.1	10.9	9.9	−0.22±0.53	0.66

*The coefficients were adjusted for school year, age at testing, and the covariates listed in Table 3. Plus–minus values are means ±SE.

†The lowest values are in the first quartile, and the highest values are in the fourth quartile.

‡This means that the expected decrement in the block-design score for an increase in average blood lead concentration from 10 to 30 μg per deciliter (0.48 to 1.45 μmol per liter) during the first three years of life is 1.8 points: 1.61 × (log[30] − log[10]) = 1.8.

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